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INDUSTRY GUIDANCE DOCUMENT ON PREPARATION OF AN ISA SUMMARY

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INDUSTRY GUIDANCE DOCUMENT ~~TO THE INDUSTRY ON FOR~~ PREPARATION OF AN ISA SUMMARY

1. INTRODUCTION

1.1 Purpose of the Industry Guidance

The *Industry Guidance Document on Preparation of an ISA Summary* will assist an applicant for a new license, or for amendment or renewal of an existing license, in the preparation of an Integrated Safety Analysis Summary (ISA Summary). This industry guidance document addresses the format, structure and content of an ISA Summary that is consistent with the requirements of 10 CFR 70. Adoption of this guidance will provide consistency in the content, style and completeness of applications submitted to the NRC and should, therefore, facilitate and expedite NRC staff reviews.

1.2 Overview of an ISA Summary

The ISA Summary is a document that is prepared after the facility or process ISA is completed. The applicant may prepare and submit to the NRC either one single ISA Summary for the entire facility or multiple ISA Summaries, for example, for each process or groups of processes. Each ISA Summary must be approved by the NRC through issuance of a Safety Evaluation Report (SER). The ISA Summary ~~It~~ is submitted with an applicant's license application for placement on the NRC public docket~~. and is not subject to NRC approval~~. Together ~~The ISA Summary, along~~ with the ISA, process safety information and other ISA supporting documentation, it must be maintained current by the licensee to serve as an up-to-date reference source on the facility's safety bases. The ISA Summary provides information on how the ISA was conducted (methodology, approach, investigators), identifies high-and intermediate-consequence ~~risk~~ accident~~s~~ sequences whose outcomes could exceed the performance requirements of 10 CFR 70.61 and provides information on items relied on for safety (IROFS) and corresponding management measures proposed to prevent or mitigate such accident sequences.

1.3 Relation of Industry Guidance to NUREG-1520

A licensee (or license applicant) must prepare a summary of the facility ISA in accordance with the requirements of 10 CFR 70.65. Chapter 3 of NUREG-1520 ('*Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility*') provides guidance on the content of an ISA and presents ~~outlines~~ Acceptance Criteria for both the ISA and ISA Summary.

The SRP Acceptance Criteria do not, however, represent the only means of satisfying the regulatory requirements and objectives. A license application may differ from the design approaches and acceptance criteria of NUREG-1520, but the applicant should, in such cases, explain how the approach will satisfy the 10 CFR 70 regulatory requirements.

The *Industry Guidance Document on Preparation of an ISA Summary* provides the applicant with guidance on how to prepare the ISA Summary. It presents a process to apply the *risk* of an accident sequence to grading the importance of IROFS and to assessing the adequacy of designated IROFS for meeting the performance criteria of 10 CFR 70.61. This guidance also includes an example of the risk-ranking and indexing of IROFS that can be used in both the ISA and ISA Summary, provided it is used consistently in both.

1.4 Risk Assessment Methodology

NUREG-1520 permits an applicant to use any risk assessment method that provides a robust and comprehensive evaluation of facility risks and demonstration of an adequate safety margin of the operation. The *Industry Guidance Document on Preparation of an ISA Summary* proposes a 'matrix approach' that entails performing an initial, qualitative evaluation of the risk of a credible accident sequence. The effectiveness of designated IROFS is incorporated into this the qualitative risk evaluation to decide if the designated IROFS and supporting management measures are adequate in number and type to meet the regulatory performance requirements of 10 CFR 70.61.

1.5 ISA and ISA Summary: Cross-Referencing of Information

An ISA Summary prepared in accordance with the methodology and guidance contained in this document should will meet the requirements of 10 CFR 70.65 and should, therefore, be acceptable to the NRC. For clarity and simplicity, information required in the ISA Summary that has been included in the license application in fulfillment of other chapters of NUREG-1520 (e.g. facility description, safety program outlines, organization and management structure) may be cross-referenced in the ISA Summary.

Information at an appropriate level of detail from the facility or process ISA should be incorporated into the ISA Summary to enable the NRC to conduct its review without a need for multiple Requests for Additional Information (RAIs). Rather than reproducing voluminous detailed information in the ISA Summary, the applicant should refer the reviewer to sources of supporting information maintained at the facility such as the ISA and its supporting analyses and databases.

1.6 Summary Introductory Comments

This guidance document describes one approach and one risk assessment method to prepare an ISA Summary to adequately establish the safety bases of the facility and to provide reasonable assurance that the facility operations will meet the regulatory performance requirements of 10 CFR 70.61. This *Industry Guidance Document on Preparation of an ISA Summary* complements NUREG-1520 and the two documents should be used in concert in conducting the ISA and preparing the ISA Summary. It does not substitute for regulations and compliance with its contents is not required. Alternate methods and solutions different from those set out in this guidance should be acceptable, if they provide a robust and rigorous basis for compliance with the requisite regulations.

2. ROLE OF THE ISA SUMMARY

2.1 NRC Use of the ISA Summary

The ISA Summary constitutes the primary source of information for use by NRC staff in evaluating a license application. It is a succinct synopsis of the results of the ISA and focuses on the higher risk, more safety-significant facility accidents that could pose a greater risk to workers, the public and the environment. The ISA Summary must provide sufficient information to the NRC staff to conduct their review and to answer the following questions:

- was the ISA conducted adequately (e.g. correct application of the selected ISA methodology, identification of all processes and all safety-significant hazards, etc.)?
- did the process hazard analyses and risk assessments correctly identify high- and intermediate-consequence ~~risk~~ accident sequences as defined by 10 CFR 70.61?
- were adequate safety controls (IROFS) designated to prevent or mitigate the consequences of high- or intermediate-consequence ~~risk~~ accident sequences?
- will the designated IROFS together with their supporting management measures provide reasonable assurance of compliance with the performance requirements of 10 CFR 70.61?
- ~~were adequate management measures identified to apply to IROFS?~~

To answer these questions and establish a level of confidence in the ISA, the NRC staff will examine facility hazards, accident sequences, accident sequence risk assessments and comparative risks, designated IROFS and management measures. The performance requirements of 10 CFR 70.61 apply to accident sequences identified by the applicant in the ISA to be high- and intermediate consequence ~~risk~~. The ISA Summary will focus on analysis of these higher risk accident sequences (cf. 10 CFR 70.61(e)) and will, therefore, present only a sub-set of the total number of facility hazards and accident sequences that were identified and analyzed in the ISA. The NRC license application review may, however, extend to examination of the ISA and supporting analyses (e.g. nuclear criticality evaluations, radiation exposure dose modeling, etc.) to ensure that the grading of accident sequence risks was correctly performed.

3. REGULATORY REQUIREMENTS FOR THE ISA SUMMARY

Regulatory requirements for the content of the ISA Summary are presented in 10 CFR 70.65(b). Information to be included in the ISA Summary can be divided into three categories: (i) information of a general nature, (ii) process-specific information, and (iii) IROFS and their supporting management measures. Information requirements for each category, the corresponding regulatory citation and the section of NUREG-1520 Chapter 3 in which the NRC expectations for such information (primarily for the ISA) are presented are all summarized in Table 1.

TABLE 1: INFORMATION REQUIREMENTS FOR THE ISA SUMMARY AND CORRESPONDING REGULATORY AND NUREG-1520 CITATIONS

Information Category and Requirement	10 CFR 70 Regulatory Citation	NUREG-1520 Chapter 3 Reference
General Information:		
• site description	70.65(b)(1)	§3.4.3.2(1)
• facility description	70.65(b)(2)	§3.4.3.2(2)
• ISA methodology description	70.65(b)(5)	§3.4.3.2(5)
• ISA team description	70.65(b)(5)	§3.4.3.2(4)
• quantitative standards for acute chemical exposures	70.65(b)(7)	§3.4.3.2(6)
• definition of terms	70.65(b)(9)	§3.4.3.2(7)
• compliance with baseline design criteria and criticality monitoring and alarms	70.64 (if applicable) & 70.65(b)(4)	§3.4.3.2(14) if applicable & §3.4.3.2(13)
Process-Specific Information:		
• description of processes analyzed	70.65(b)(3)	§3.4.3.2(3)
• identification of hazards	70.65(b)(3)	§3.4.3.2(9)
• general types of accident sequences	70.65(b)(3)	§3.4.3.2(10)
• unmitigated risk ranking (typically into three tiers)	70.65(b)(3)	§3.4.3.2(10)
• characterization of intermediate- and high-risk accident sequences	70.65(b)(3)	§3.4.3.2(8)
Items Relied on For Safety:		
• list and description of IROFS at the systems level	§70.65(b)(6)	§3.4.3.2(11) & (8)
• IROFS management measures	§70.65(b)(4)	§3.4.3.2(11) & (8)
• sole IROFS	§70.65(b)(8)	§3.4.3.2(12) & (8)

4. FORMAT AND CONTENT OF THE ISA SUMMARY

4.1 Content Overview

The ISA Summary should present the information listed in Table 1. ~~will include the results of process risk assessments, descriptions of the principal elements of proposed safety programs and descriptions of IROFS and their associated management measures.~~ Detailed operating procedures, detailed program descriptions or detailed information on facility operation management are not required in the ISA Summary.

4.2 ISA Summary Structure

The ISA Summary can logically be structured into three sections entitled: '*General Information*', '*Process-Specific Information*' and '*Items Relied on For Safety*'. The general types of information that should be discussed in each section are summarized below. The detailed information that should be included in each section is presented in Chapter 6 of this guidance document.

4.2.1 ISA Summary Section 1: General Information

Information applicable to the facility and site and all processes analyzed in the ISA should be presented in this section. It should include the following:

- ✓ facility and site descriptions
- ✓ ISA methodology description
- ✓ ISA team composition and member qualifications
- ✓ quantitative standards selected for acute chemical exposure
- ✓ definitions of unlikely, highly unlikely, and credible
- ✓ typical hazards analyzed for the facility, including chemical hazards
- ✓ if applicable, statement that there are no IROFS solely relied on for safety
- ✓ compliance with criticality monitoring and alarms (10 CFR 70.24)
- ✓ compliance, if applicable, with baseline design criteria (10 CFR 70.64)

4.2.2 ISA Summary Section 2: Process-Specific Information

Information in this section will include a summary of risk and safety assessments performed for each process analyzed in the ISA. Information should include:

- ✓ processes analyzed
- ✓ process hazards identified
- ✓ general types of accident sequences

- ✓ risk assessment and ranking for unmitigated accident sequences
- ✓ characterization of intermediate- and high-consequence ~~risk~~ accident sequences
- ~~description of designated IROFS~~ [Comment: relocated to §4.2.3.]
- ~~description of management measures~~ [Comment: relocated to §4.2.3.]
- ✓ risk assessment of mitigated accident sequences and demonstration of compliance with 10 CFR 70.61 performance requirements

4.2.3 ISA Summary Section 3: Items Relied on For Safety Information

Information in this section includes lists and descriptions of IROFS designated in the ISA:

- ✓ description of IROFS for high- and intermediate-consequence ~~risk~~ accident sequences
- ✓ description of designated IROFS
- ✓ IROFS for accident sequences that are the sole item preventing or mitigating a high- or intermediate-risk accident sequence
- ✓ description of management measures supporting each IROFS

5. RISK ASSESSMENT METHODOLOGY

5.1 Risk Assessment

The heart of the ISA is the risk assessment that is performed on process and facility accident sequences. Results of the risk assessment are used to rank the comparative risks of different accident sequences (or initiating events for one accident sequence) and to establish the need for compensating safety controls, or IROFS, to prevent or mitigate the effects of such an accident.

The ISA Summary must describe and justify the appropriateness of the risk assessment methodology used in performing the ISA. The ISA Summary must convey that the risk analysis provides reasonable assurance that high-consequence ~~risk~~ accident sequences will be highly unlikely and that intermediate-consequence ~~risk~~ accident sequences will be unlikely.

5.2 Methodology Overview

The *Industry Guidance Document on Preparation of an ISA Summary* proposes a four-step, qualitative '*Index Method~~'~~ for R~~r~~isk A~~a~~ssessment*'. In the first step, an accident sequence is established to be '*credible*' or '*not credible*'. Any '*credible*' accident sequence will have IROFS applied and any '*incredible*' accident sequence will neither be analyzed further in the ISA nor considered in the ISA Summary. The second step entails calculation of a Matrix Risk Factor based on qualitative estimates of the likelihood of occurrence and severity of consequences of the accident sequence. The Matrix Risk Factor provides a qualitative measure of the risk in the third step of the process ~~of the risk that~~ against which the designated IROFS must protect~~. against~~. In the final step, the Matrix Risk Factor is modified ~~evaluated~~ taking into account the effectiveness of any designated IROFS, and compared again to various 'risk zones'. This comparison is used to demonstrate that the IROFS are sufficient in number and effectiveness to provide reasonable assurance that the performance requirements of 10 CFR 70.61 will be met. This demonstration satisfies the regulatory requirements of 10 CFR 70.65(4).

The '*Index Method~~'~~ for ~~r~~Risk A~~a~~ssessment*' is fully explained in Appendix A.

6. DETAILED CONTENT OF THE ISA SUMMARY

This chapter provides guidance on what detailed information should be included in each of the three sections of the ISA Summary. The ISA Summary should not contain detailed procedures or in-depth technical information; such detailed information is available for inspection at the facility either in the ISA or in the supporting ISA analyses and documentation.

6.1 ISA Summary Section 1: General Information

- ✓ *Facility Description*: information should be included on facility features that could affect potential accidents and the reliability and availability of IROFS. Examples include: facility location, facility design information, and the location and arrangement of buildings. The facility description can reference and build upon information provided in Chapter 1 of the license application (NUREG-1520, Chapter 1, *General Information*).

- ✓ *Site Description*: information on factors that could affect facility safety, such as natural phenomena, transport corridors and nearby industrial operations, should be included. The geographical setting, regional demographic information and susceptibility to natural phenomena should be detailed. Information on geography, meteorology (e.g., high winds and flood potential), seismology, and demography should be provided. The site description can reference and build upon the general information provided in Chapter 1 of the license application (NUREG-1520, Chapter 1, *General Information*).

- ✓ *ISA method(s)*: a summary of the method(s) and analytical techniques used to conduct the ISA should be presented. Specific methods used to identify hazards, to analyze process hazards, to identify accident sequences and to establish their comparative risk (through severity of consequence and likelihood of occurrence analysis) should be summarized. If analysis methods described in NUREG-1513 ('*ISA Integrated Safety Analysis Guidance Document*') were used, only reference need only be made to those that were chosen. Detailed method descriptions are not required in this case.~~.~~ Information presented in Chapter 3 of the license application (NUREG-1520, Chapter 3, *Integrated Safety Assessment*) can be referenced.

- ✓ *ISA Team*: the composition and qualifications of the team(s) that conducted the ISA should be described. The areas of technical expertise of ISA team members (e.g. hazard analysis, process design, radiation safety, etc.) should be stated along with the teams' experience and qualifications in conducting ISAs. Information presented in Chapter 3 of the license application (NUREG-1520, Chapter 3, *Integrated Safety Assessment*) can be referenced.

- ✓ *Selection of Quantitative Standards*: quantitative standards used in the ISA to assess consequences from acute chemical exposure to licensed material or hazardous chemicals produced from licensed material must be identified. Information presented in Chapter 3 of the license application (NUREG-1520, Chapter 3, *Integrated Safety Assessment*) can be referenced.

- *Definitions of Likelihood Terms*: definitions of the following three terms as they are used in the ISA are required: credible, unlikely and highly unlikely. ~~Example definitions are provided in Appendix B of this document.~~ Information presented in Chapter 3 of the license application (NUREG-1520, Chapter 3, *Integrated Safety Assessment*) can be referenced.

- ✓ *Hazards Analyzed*: descriptions of the types of hazards analyzed for each process (including any unique or specific hazards) should be provided. Information presented in Chapter 3 of the license application (NUREG-1520, Chapter 3, *Integrated Safety Assessment*) can be referenced.

- *IROFS Solely Relied on For Safety*: if there are no '*sole items relied on for safety*' in the ISA, this fact should be acknowledged in this Section 1 of the ISA Summary.

- ✓ *Criticality Monitoring and Alarms*: information and programmatic commitments must be provided, most likely through reference to Chapter 5 of the license application '*Nuclear Criticality Safety*' ~~(NUREG-1520, Chapter 5)~~, that demonstrate compliance with provisions of 10 CFR 70.24

- ✓ *Baseline Design Criteria (BDC):* if the license application is for a new facility or a new process at an existing facility (that requires a license amendment under 10 CFR 70.72), the ISA Summary must document how the BDC of 10 CFR 70.64 were incorporated into the process design.

6.2 ISA Summary Section 2: Process-Specific Information

- ✓ *Processes Analyzed*: a tabulation of all processes analyzed in the ISA should be provided. Processes should be described at the systems level, but in~~with~~ sufficient detail to explain the theory of operation, permit an understanding of hazards and risks of potential accidents and to document how any designated IROFS prevent the process conditions from exceeding the performance requirements of 10 CFR 70.61. This tabulation can be presented using a 'top-down' approach:

    - **Facility**: the top level of detailed analysis would the cover the facility and apply, for example, to a facility with limited operations, such as rod loading and assembly completion

- **Building**: the next level of detail would be on the building level. This application would be for a facility that has multiple buildings that have a limited number of processes in each
- **Product Line**: the next level of detail would be by product line. This application would be for a facility that has several product lines, such as conversion of UF_6 to UO_2 powder, scrap recovery, or a powder-to-pellet operation
- **Sub-Process**: the lowest detailed level would be a specific sub-process in a product line or building. Examples would include pelleting, dissolving uranium-bearing scrap, or packaging for shipment
- **Combined Approach**: combining different levels of detail is acceptable. For example, one analysis could ~~should~~ be adequate for capturing the hazards in a building that includes just a few processes. However, an adjacent building may ~~would likely~~ require a product line analysis with a specific sub-process analysis.

For each process analyzed in the ISA a narrative process description accompanied by a simple block flow diagram should be provided. A logic diagram or fault tree incorporating the process and each designated IROFS could also be used. Information on the chemical and physical transformations that occur in the process should be stated.

The ISA Summary should also explain how the methodology described in Section 1 of the ISA Summary for classifying the comparative risks of accident sequences was used in the risk analysis of processes. Accident sequences that are classified as 'low-consequence ~~risk~~' do not require application of IROFS and can be eliminated from any further consideration in the ISA Summary.

✓ *Process Hazards*: hazards that were identified in the ISA specific to each process should be enumerated.

✓ *General Types of Accident Sequences*: general types of accident sequences that were identified in the ISA for each process should be identified. Accident sequences can be grouped in one of several ways, such as having the same initiating event, experiencing failure of the same IROFS, resulting in the same type and severity of consequences, etc.). For example, several processes each having a set of functionally identical IROFS can be considered the same type and listed and described only once. For simplicity, the applicant may describe the general principles of use of a particular safety control (e.g. geometry control, concentration control), but supplement this description

with additional detailed information for a specific application of the safety control, if required.

- ✓ *Process Risk Assessment*: the results of the risk assessment performed for each process should be presented. The following information should be provided:

    - unmitigated consequences for each general type of accident sequence
    - comparison of the unmitigated consequences to the performance requirements of 10 CFR 70.61 and designation of each as a '*high consequence event*' (10 CFR 70.61(b)), an '*intermediate consequence event*' (10 CFR 70.61(c)) or an event of no regulatory concern (low consequence event)
    - likelihood of occurrence of each general type of accident sequence, expressed in terms of the definitions of credible, unlikely and highly unlikely ~~in Appendix B.~~
    - classification of the unmitigated (i.e. uncontrolled) risk of each general type of accident sequence
    - classification of the mitigated (i.e. controlled) likelihood of occurrence of each general type of accident sequence (following application of IROFS)
    - classification of the mitigated (i.e. controlled) risk of each general type of accident sequence

- ✓ *IROFS*: a description should be provided of IROFS designated for each general type of accident sequence. The description should identify the essential features of the item, the safety parameter that it controls and, for administrative control IROFS, the nature of the action(s) to be performed. Classification of each IROFS by type (passive engineered, active engineered, augmented administrative, administrative) should be provided and, if applicable, an explanation of how such IROFS were graded according to their safety-importance.

- ~~*Management Measures*: a description of those management measures to be applied to each IROFS and how they will be applied should be provided and, if such measures were graded in accordance with the safety significance of the IROFS, how such grading was performed.~~ [Comment: relocated to §6.3]

6.3 ISA Summary Section 3: IROFS

Section 3 of the ISA Summary contains lists of IROFS designated for high- and intermediate-consequence~~risk~~ accident sequences identified in the ISA.

- ✓ *Management Measures*: a description of those management measures to be applied to each IROFS should be provided and, if such measures were graded in accordance with the safety significance of the IROFS, how such grading was performed. For simplicity, the applicant may wish to outline the general features and principal elements of a management measure (e.g. worker training) and provide additional information for specific applications, if required. Similarly, the applicant may wish to outline levels of management measure grading and discuss application to specific IROFS with supplement information. For example, application of the Preventive Maintenance management measure may be at a high (e.g. daily), intermediate (e.g. monthly) or low (e.g. annual) frequency depending on the importance to safety of the IROFS.

- ✓ *IROFS List*: a tabulation of all IROFS identified for high-and intermediate-consequence ~~risk~~ accident sequences should be provided. Each IROFS should be identified and its function explained in sufficient narrative detail to enable the NRC staff reviewer to understand how it will allow the performance requirements of 10 CFR 70.61 to be satisfied.

- ✓ *Sole IROFS List*: a tabulation of IROFS that are the sole item preventing or mitigating a high- or intermediate-risk accident sequence should be prepared. The 'Sole IROFS List' will be a sub-set of the above comprehensive list of all IROFS.

APPENDIX A

INDEX METHOD FOR RISK ASSESSMENT

A.1 Introductory Comments

Appendix A is not an integral part of this industry guidance document and the information it develops is not all included in the ISA Summary. Appendix A outlines one method for conducting the risk assessment (that is applied to an example in Appendix B) and that forms an integral component of the ISA Summary. There are numerous methods other than that presented in Appendix A to conduct a risk assessment.

A.~~1~~2 Method Overview

Appendix A presents an '*Index Method for Risk Assessment*' to assess the risk of accident sequences identified for individual facility processes. Risk is estimated qualitatively by means of a Matrix Risk Factor that is based upon the likelihood of occurrence of each accident sequence and the severity of its consequences. Only ~~the risk of~~ *credible* accident sequences – that is, accidents that are expected to occur during the life of a facility or process – are ~~is~~ evaluated in the ISA process. ~~and only credible accident sequences that could exceed the performance requirements of 10 CFR 70.61 need be addressed in the ISA Summary.~~

For simplicity, ~~convenience,~~ a 3x3 matrix of '*accident likelihood*' and '*accident severity of consequences*' is used in this guidance document to determine if mitigative measures, or IROFS, are required to protect against an accident sequence. ~~assess accident sequence risk. A larger matrix could be used, for example, to further sub-divide a likelihood or consequence category, or to include low-risk accident sequences that need not be reported in the ISA Summary.~~ The unmitigated accident's Matrix Risk Factor ~~is compared to various risk zones ('*high risk*', '*intermediate risk*') to~~ establishes the risk that must be protected against by the IROFS.

Following designation of one or more IROFS, the Matrix Risk Factor is recalculated for the mitigated accident sequence by taking into account the effectiveness of any designated IROFS. This revised Matrix Risk F~~f~~actor is again compared to the risk zones to ensure that the designated IROFS are adequate both in number and effectiveness to provide reasonable assurance that the performance requirements of 10 CFR 70.61 will be satisfied.

The *Index Method of Rrisk Aassessment* methodology consists, therefore, of four steps:

(1) **Establish Accident Credibility**: assess whether the accident sequence is credible. If the accident sequence is not credible, no risk assessment need be performed. If the accident is credible, the assumption is made that IROFS will be required.
(2) **Compute Matrix Risk Factor**: compute a Matrix Risk Factor based upon the forecast likelihoodestimated frequency of the initiating event and the severity of the unmitigated consequences of the accident sequence
(3) **Determine Risk of Unmitigated Accident Sequence**: establish the risk level that any designated IROFS must protect against
(4) **Assess Adequacy of Designated IROFS for the Mitigated Accident Sequence**: the likelihood of occurrence of the mitigated accident sequence is reduced by taking into account the effectiveness of the number and type of designated IROFS. The reduction in accident likelihood is compared to various risk zones to verify that the designated IROFS are adequate for reducing the accident's risk to an acceptable level.

A.2 Method Implementation

The *Index Method of Rrisk Aassessment* is applied in the following manner:

Step 1: Establish Accident Credibility

Each accident sequence identified in the Process Hazards Analysis is first assessed and classified to be either '*credible*' or '*incredible*'. One definition for '*credible*' is presented in Appendix B. Only accidents that are deemed 'credible' need to be evaluated in the ISA and considered for inclusion in the ISA Summary. A 'credible' accident in this Index Method is one that is expected to occur during the life of the facility.

Step 2: Estimate Accident Likelihood and Consequences Compute Matrix Risk Factor

The risk of each credible accident sequence is evaluated without consideration of any prevention measures (IROFS) (i.e. unmitigated or uncontrolled). A Matrix Risk Factor for the accident is computed as the product of a qualitative assessment of the accident likelihood and its forecast severity of consequences.

The *likelihood of occurrence* of the accident is dependent upon the frequency of occurrence of an initiating event. A qualitative assessment is used to establish numerical scores Qualitative numerical values for accident likelihood based upon the guidelinesare presented in Table A-1. Three levels of likelihood are used in the 3x3 risk matrix: highly unlikely,

unlikely and likely (equivalent to 'not unlikely'). The term 'life cycle of the system' in Table A-1 is dependent upon the component, piece of equipment or process operation that is under consideration and must be specified by the applicant. For example, the life cycle of an ADU line may be 30 years, whereas that for a short-term maintenance system may be one year.

TABLE A-1

QUALITATIVE NUMERICAL VALUES FOR THE LIKELIHOOD OF OCCURRENCE OF THE UNMITIGATED ACCIDENT

Numerical Value	Qualitative Description
3	Likely to occur sometime (or repeatedly) during the life cycle of the system
2	Unlikely to occur during the life cycle of the system
1	Highly unlikely to occur during the life cycle of the system

The *severity of consequences* of an accident sequence is measured in terms of resulting health effects (including fatalities) and comparison with the personnel exposure limits of 10 CFR 70.61. Based upon the accident's potential adverse effects for four facility hazards -- chemical, fire, nuclear criticality, radiological -- a ~~qualitative~~ numerical score is assigned for the severity of consequences. Severity of consequences is assigned to one of three categories~~: in the 3x3 risk matrix~~: '*high consequence*', '*intermediate consequence* ~~*(off-site)*~~', and '*low* ~~*intermediate*~~ *consequence* ~~*(on-site)*~~'. Accident sequences determined to have low consequences need not be further analyzed. ~~In this model the risk of off-site intermediate-consequence events is assumed to be greater than for on-site events, principally because accidents at Part 70 facilities are generally very localized. Any off-site effects would be clearly indicative of a very serious plant failure. The performance requirements of 10 CFR 70.61 present criteria for on-site consequences to workers and off-site consequences to members of the public and the environment outside of the facility's controlled area. For consistency, these three measures of consequence severity have been adopted. Table A-2 defines the severity of consequences for each category in terms of the four facility hazards and the 10 CFR 70.61 performance requirements.~~

Step 3: **Determine Risk of the Unmitigated Accident Sequence**:
The three possible measures of '*likelihood of occurrence*' and '*severity of consequences*' may be represented as a 3x3 matrix. The performance requirements of 10 CFR 70.61 may be added to this matrix to illustrate

what combinations of likelihood and consequences are permissible and do not require mitigation by IROFS. For example, a high-consequence accident that is highly unlikely or an intermediate-consequence accident that is unlikely will not need any IROFS. Whether an accident sequence requires IROFS can be ascertained visually on the 3x3 matrix or by computing the value of the ~~The~~ Matrix Risk Factor (product of the numerical scores assigned to likelihood and consequence) and comparing it to the shaded risk zones shown on the Table A-2 matrix. ~~computed~~ In the present model, if the value of the Matrix Risk Factor is greater than or equal to 6, IROFS(s) will be needed. ~~in Step 2 is plotted on the 3x3 risk matrix (Table A-3). The value of this factor establishes the importance of any IROFS that are applied to prevent the accident or to reduce its risk to an acceptable level.~~

TABLE A-2

RISK ASSESSMENT TABLE FOR UNMITIGATED ACCIDENT SEQUENCES ILLUSTRATING MATRIX RISK FACTORS

		LIKELIHOOD OF OCCURRENCE		
		Highly Unlikely (1)	Unlikely (2)	Likely (3)
SEVERITY OF CONSEQUENCE	High (3)	3	6	9
	Intermediate (2)	2	4	6
	Low (1)	1	2	3

Accident sequences whose 'likelihood of occurrence' and 'severity of consequence' numerical scores necessitate designation of IROFS

Step 4: **Assess Adequacy of Designated IROFS and Mitigated Accident Sequence**:

The risk of an accident sequence is reduced through application of different numbers and types of IROFS. As the severity of consequences of an accident can generally not be changed, IROFS are applied to reduce its

likelihood of occurrence. The *Index Method* *of Risk Assessment* 'credits' (i.e. reduces) the likelihood of occurrence of the unmitigated accident sequence to reflect both the number and robustness of different IROFS that are designated for an accident sequence. Reducing the numerical likelihood score will shift the Matrix Risk Factor Index in the direction of a lower risk zone.

Numerical values assigned to ~~for~~ different types of IROFS (administrative, augmented administrative, active engineered, passive engineered) are listed~~presented~~ in Table A-~~4~~3.

TABLE A-2

SEVERITY OF CONSEQUENCES OF THE UNMITIGATED ACCIDENT

Numerical Value	Qualitative Descriptor (Consequences of Event)	Facility Hazard Type			
		Chemical	Fire	Nuclear Criticality	Radiological
3	High Consequence *Fatality or multiple permanent health effects*	An acute chemical exposure to an individual from licensed material or hazardous chemicals produced from license material that could endanger the life of the worker or lead to irreversible or other serious long-lasting health effects to a member of the public at the site boundary.	Fire which could cause commensurate radiological, criticality or chemical consequences	Occurrence of a nuclear criticality which could cause commensurate radiological effects.	Acute worker dose of 100 rem, acute dose at site boundary of 25 rem or intake at site boundary of 30 mg soluble uranium
2	Intermediate Consequence (Off-Site) *Mild transient health effects*	An acute chemical exposure to an individual from licensed material or chemicals produced from licensed material that could lead to mild transient health effects to a member of the public at the site boundary.	Fire which could cause commensurate radiological or chemical consequences	Not Applicable	Acute dose at site boundary of 5 rem or 24 hour average release exceeding 5000 times Table 2 of 10 CFR 20, Appendix B
1	Intermediate Consequence (On-Site) *Permanent loss of function/limb or multiple lost-time injury*	An acute chemical exposure to an individual from licensed material or chemicals produced from licensed material that could lead to irreversible or other serious long-lasting effects to a worker.	Fire which could cause commensurate radiological or chemical consequences	Not Applicable	Acute worker dose of 25 rem

~~TABLE A-3~~

~~RISK ASSESSMENT TABLE FOR UNMITIGATED ACCIDENT SEQUENCES ILLUSTRATING MATRIX RISK FACTORS~~

		~~LIKELIHOOD OF OCCURRENCE~~		
		~~Highly Unlikely (1)~~	~~Unlikely (2)~~	~~Not Unlikely (3)~~
SEVERITY OF CONSEQUENCE	~~High (3)~~	~~3~~	~~6~~	~~9~~
	~~Intermediate (Off-site) (2)~~	~~2~~	~~4~~	~~6~~
	~~Intermediate (On-site) (1)~~	~~1~~	~~2~~	~~3~~

TABLE A-34

QUALITATIVE NUMERICAL VALUES FOR THE EFFECTIVENESS OF IROFS PROTECTION

Numerical Value	Description of IROFS
1	Protection by a single, trained operator with adequate response time (administrative)
2	Protection by a single hardware system, functionally tested on a regular basis (active engineered)
3	Protection by a single passive-engineered safety device, functionally tested on a regular basis *or* a single, tested hardware system with trained operator back-up
4	Protection by two independent, redundant hardware systems, each functionally tested on a regular basis (e.g. geometry)

The unmitigated likelihood index selected in Step 2 is adjusted by subtracting the appropriate IROFS score (from Table A-3) and then the appropriate risk zone is identified in Table A-4 by identifying the final adjusted likelihood index. ~~Matrix Risk Factor is adjusted by subtracting the appropriate IROFS score from the likelihood of occurrence assigned in Step 2 and then comparing it to the risk zones shown in Table A-5. Two~~

~~examples are presented below to illustrate how the likelihood adjustment is made to establish the adequacy of designated IROFS. In the second example, two sets of control parameters are applied to mass to illustrate application of different administrative and passive engineered controls.~~

Example #1 of Likelihood Adjustment:

- Accident sequence: accident having a nuclear criticality potential
- Unmitigated accident likelihood (from Table A-1): 3 (likely)
- Unmitigated accident severity of consequences (from Table A-2): 3 (high)
- Unmitigated accident Matrix Risk Factor: 9 (unacceptably high risk)
- IROFS credits for reducing likelihood (from Table A-4):
  - safe geometry vessel: 4
  - concentration control by operator: 1
- revised likelihood value: -2 (computed as 3 - 4 - 1 = -2)
- risk zone (on Table A-5): Risk Zone 3 (acceptable)

Example #2 of Likelihood Adjustment:

- Accident sequence: accident having a nuclear criticality potential
- Unmitigated accident likelihood (from Table A-1): 3 (likely)
- Unmitigated accident severity of consequences (from Table A-2): 3 (high)
- Unmitigated accident Matrix Risk Factor: 9 (unacceptably high risk)
- First attempt at likelihood reduction:
  - IROFS credits for reducing likelihood (from Table A-4):
    - mass control (weigh scale + 1 operator): 1
    - moderation control (in-line moisture monitor of moisture, taken on a regular basis): 2
  - revised likelihood value: 0 (computed as 3 - 1 - 2 = 0)
  - risk zone (on Table A-5): Risk Zone 2 (*not* acceptable for permanent solution, but that would permit continued operation of the process)
- Second attempt at likelihood reduction:
  - IROFS credits for reducing likelihood (from Table A-4):
    - mass control (weigh scale + interlock system): 2
    - moderation control (in-line moisture monitor of moisture, taken on a regular basis): 2
  - revised likelihood value: -1 (computed as 3 - 2 - 2 = -1)

The likelihood-consequence matrix used in Step 4 has been modified from that illustrated in Table A-2 in three ways. First, the lowest category of 'severity of consequences' has been deleted as no accident sequence having low-consequences will exceed the 10 CFR 70.61 performance requirements

and need not be considered in the ISA Summary. Second, the "intermediate-consequence" category has been subdivided into two categories: '*off-site intermediate-consequence*' and '*on-site intermediate-consequence*' events. In this model, the severity of consequence of an off-site intermediate-consequence event is assumed to be greater than an on-site intermediate-consequence event. While the risk of an off-site event will probably be minor due to the highly localized character of facility accidents, the adverse public perception could make such an accident into a serious public relations challenge. Third, ~~In Table A-5~~ the number of likelihood categories has been increased from three to six to accommodate the new range of values resulting from application of the IROFS scores in Table A-3~~effectiveness factors~~ to the likelihood of occurrence scores.

TABLE A-~~4~~5

RISK ASSESSMENT TABLE FOR ASSESSING THE ADEQUACY OF IROFS TO MEET THE PERFORMANCE REQUIREMENTS OF 10 CFR 70.61

SEVERITY OF CONSEQUENCE	LIKELIHOOD OF OCCURRENCE					
	Highly Unlikely		Unlikely		Not Unlikely (Likely)	
	-2	-1	0	1	2	3
High (3)						
Intermediate (Off-site) (2)						
Intermediate (On-site) (1)						

Risk Zone 1: (Does not meet performance requirements. Immediate corrective action required.)

Risk Zone 2: (Does not meet the performance requirements. However, a sufficient margin of safety is present to allow

continued operation for a specified period to allow for correction.)[1]

☐ Risk Zone 3: (Meets the performance requirements. No corrective action is required. Acceptable for start-up of a new operation)

When two concurrent events (contingencies) are identified that result in a condition whereby a criticality is possible, the two elements of the accident likelihood ((i) frequency of the initiating event, and (2) the reliability or effectiveness of the IROFS that protect against the event progressing to the accident) -- are used to demonstrate compliance with the Double Contingency Principle (i.e., two unlikely, independent, and concurrent changes in process conditions must occur before criticality is possible). The first element (frequency of the initiating event) determines the qualitative probability that an event will occur despite prevention measures in place. The second element (effectiveness of IROFS) determines the qualitative probability that another event will not occur concurrently resulting in a condition whereby a criticality is possible. In each case, the quality of the measures in place designed to preclude these events is determined based upon the reliability and availability of the measures to function when required.

[1] For existing licensees 10 CFR 70.62(c)(3)(ii) requires that any unacceptable performance deficiencies be corrected within four years of the effective date of the rule. The ISA Summary may be submitted anytime within the four year period and an SER approval issued, but the deficiencies do not need to be remedied prior to the expiration of the four year implementation period.

APPENDIX B

DEFINITIONS OF LIKELIHOOD TERMS

Definitions for three terms -- credible, unlikely, highly unlikely -- as they were used in the ISA must be included in the ISA Summary (in accordance with 10 CFR 70.65(b)(9)). Example definitions for each are provided below. Quantitative definitions, such as those proposed in NUREG-1520, Chapter 3 (Appendix A), or other definitions that provide a basis for compliance with 10 CFR 70 regulations, should be equally acceptable.

Credible: events and conditions that *could* occur during the life of a facility. Events and conditions that will not occur during the life of the facility do not need to be evaluated in the ISA.

Unlikely: an event or condition that has at least one robust barrier to prevent failure.

Highly Unlikely: an event or condition that has at least two independent robust barriers to meet the double contingency criteria to prevent failure

APPENDIX BC

PROCESS RISK ASSESSMENT EXAMPLE

An example of a risk assessment for one hypothetical process -- a dissolver operation for uranium oxide scrap recovery -- is developed in this Appendix BC. This working example is provided as an example for fulfillment of Section 2 ('*Process-Specific Information*') and Section 3 ('*IROFS*') of the ISA Summary. The risk assessment methodology used is that presented in Chapter 5 and Appendix A of this *Industry Guidance Document on Preparation of an ISA Summary*. Risk assessment methods different from those set out in this guidance will be acceptable if they provide a thorough and robust basis for demonstrating compliance with applicable 10 CFR 70 regulations.

Appendix BC is presented in two sections. Section 1 steps through an analysis of the uranium dissolver operation for each topic to be discussed in the ISA Summary (see chapters 4.2.2 and 4.2.3 of this document). Section 2 presents the information for the uranium dissolver analysis that should be included in the ISA Summary.

BC.1 Section 1: Process Risk Analysis

(a) *Process Analyzed*:

(i) **Process Identity**: Uranium Oxide Dissolver

(ii) **Operational Configuration**: the uranium dissolver operation is designed to recover uranium oxide from filings produced in the grinding of sintered fuel pellets prior to their placement in fuel assemblies. This batch operation entails transfer of a measured quantity of uranium oxide filings (≈ 15 kgs) is fed from a safe-geometry hopper into a vertical, cylindrical, steel-walled tank of safe geometry (8" in diameter, ____ liter capacity) containing heated, concentrated nitric acid (≈ 60%). The uranium oxide solids are dissolved in an exothermic reaction and converted into soluble uranyl nitrate. At the end of a dissolution cycle, the uranyl nitrate solution is pumped from the dissolver, passed through several filters and transferred to a solvent extraction circuit for impurity removal. The uranyl nitrate solution is analyzed both for its uranium content and to ensure sufficient free acid (≈ 5%) is present to maintain the uranium in the soluble form. A Bblock Fflow diagram of the dissolver is presented below:

BLOCK FLOW DIAGRAM
(to be developed)

(iii) **Safety Design Basis**: process safety is primarily assured by satisfying the Double Contingency/Defense in Depth Principle ('*...at least two unlikely, independent and concurrent changes in process conditions, or failures of multiple independent and reliable controls on a single process condition would be required before a nuclear criticality accident would be possible...*')

(b) *Process Hazards*:
Three process hazards were identified:

(1) **nuclear criticality hazard**
(2) **chemical hazards**: toxic chemical hazards from two chemicals of concern:
- Nitric Acid (70%): toxic by inhalation, ingestion or skin contact. Heated and added to dissolver
- Uranium Compounds: (e.g. UO_2, $UO_2(NO_3)_2 \cdot 6H_2O$, U_3O_8) chemically toxic. Primarily addressed as a radiation hazard

(3) **radiological hazards**: the primary radiological hazard is a nuclear criticality. Additional exposure may result from inhalation of uranium oxide dust during solids transfer and from the uranyl nitrate solution and exposure to, or inhalation of, dissolver off-gases containing nitric acid and uranyl nitrate

(c) *General Types of Accident Sequences*:

Accident scenarios and their causes (initiating events) were developed by considering deviations from normal modes of operation. Credible upset conditions were developed for each identified hazard:

(1) **nuclear criticality hazards**:
Credible Upset Conditions:
(The loss of a barrier or controlled parameter was assumed to be the initiating event in every accident sequence.)
(i) exceeding concentration limits
(ii) violating favorable geometry parameters (dissolver volume)
(iii) violating spacing limits

General Types of Accident Sequences:
(i) addition of too many solids (exceed dissolver concentration limit)
(ii) plugging of in-line filters on dissolver discharge line
(iii) incorrect spacing between dissolver and other tanks and containers brought into the dissolver room containing uranium
(iv) precipitation of uranyl nitrate due to insufficient free acid

(2) **chemical accident hazards**:

Credible Upset Conditions:

(i) reagent or solids spillage

(ii) dissolver off-gases (containing nitric acid and uranium)

General Types of Accident Sequences:

(i) loss of containment (leaks, spills from corrosion)

(ii) overfilling of dissolver vessel

(iii) spillage of nitric acid during addition to dissolver

(iv) inadvertent addition of excessive solids

(v) inadvertent reversal of solids-to-acid addition sequence

(vi) failure to use correct nitric acid strength

(vii) worker exposure to acidic and radioactive off-gases

(3) **radiological hazards**:

Radiation hazards may arise from internal exposure (breathing contaminated air) and external exposure (radiation levels).

Credible Upset Conditions:

(i) spillage of solids being transferred to dissolver

(ii) loss of containment of dissolver contents (spillage)

General Types of Accident Sequences:

The only general type of accident sequence that could result in significant radiological exposure to a worker is an inadvertent nuclear criticality. These accident scenarios are discussed under the '*nuclear criticality hazard*' section above.

(d) *Process Risk Assessment*:

For eEach general type of accident sequence identified for the dissolver the integrated risk assessment process explained in Appendix A was used to assign numerical scores to 'likelihood of occurrence' and 'severity of consequences'. These data , estimates of severity of consequences and likelihood, computation of the Matrix Risk Factor and comparison to the performance requirements of 10 CFR 70.61 are presented in Table BC-1.

In the risk analysis of Cchemical Aaccident Hhazards, quantitative standards for acute exposure must be specified (e.g. Acute Exposure Guideline Level (AEGL) values). The AEGL values for acute exposure to nitric acid are:

Severity of Consequences	Quantitative Acute Exposure Standard	Numerical Values	
		mg/L	mg/m^3

High	AEGL-3	13	34
Intermediate (Off-Site)	<AEGL-3 & >AEGL-2	4-12	10-33
Intermediate (On-Site)	<AEGL-2 & >AEGL-2	4-120.5-3	10-331.3-9

The principal occupational risks posed by the dissolver operation are the effects of a nuclear criticality. Nuclear criticality safety is based upon controlling geometry and uranium concentration. Use of geometry and uranium concentration as controlled parameters satisfies the Double Contingency/Defense-In-Depth Principle.

There are no potential off-site impacts from this process, and thus, no accident sequences having an '*Intermediate - Off-Site*' severity of consequence classification.

(e) *IROFS*:

ThreeFour types of IROFS are used in the uranium dissolver operation:

(1) Passive Engineered Controls: consist primarily of containment systems (e.g. process liquid piping, chemical tanks, vessels, columns, spill dikes), dissolver vessel dimensions and fixed pacing between equipment. Containment systems are designed for chemical compatibility/resistance and anticipated service conditions (temperature and pressure).

(2) Active Engineered Controls: used primarily to control the flow of solids and liquids into and out of the dissolver and to prevent releases of hazardous vapors, acid and uranyl nitrate solutions and radioactivity to the process work area. These controls consist of in-line monitors, valves that fail to the closed position, high level alarms, pump shut-offs/activations and automatic chemical addition.

(3) Administrative Controls (including Enhanced Administrative): consist of operator actions such as opening valves pumps and other equipment to maintain containment of chemical hazards, controlling feed stream flow rates, pH probes, sampling of the dissolver contents and performance of preventive maintenance. Personnel Protective Equipment (PPE) worn by operators (e.g. chemical resistant gloves, safety glasses) is considered a passive control.

The IROFS designated for each general type of accident sequence and controlled parameters for each, as well as the 'IROFS effectiveness' credit applied to the Matrix Risk Factor are presented in Table BC-2.

(f) *Management Measures*:

IROFS must be~~are~~ maintained to ensure their reliability and availability. Active and passive engineered controls are maintained by means of the facility change control process and through testing and/or inspection programs. Administrative controls are specified in area operating procedures or plant-wide procedures (e.g. ~~N~~nuclear ~~C~~criticality ~~S~~safety ~~P~~procedure ~~M~~manual, ~~I~~industrial ~~H~~health and ~~S~~safety ~~P~~procedure ~~M~~manual). Training programs increase the reliability of administrative controls while inspections and audits verify compliance with administrative controls. Administrative controls protecting against the mixing of incompatible chemicals are aided by proper identification of equipment and containers. Operators are periodically trained on existing procedures and postings and on all revised and new procedures and postings prior to implementation. In the case of ~~N~~nuclear ~~C~~criticality ~~S~~safety, NCS inspections and periodic area NCS audits verify compliance with administrative controls.

Management measures applied to each type of IROFS are summarized ~~specified~~ in Table B~~C~~-2. Detailed information for each management measure -- for example on maintenance surveillance methods and frequencies, whether an IROFS is fail-safe, self-indicating or monitored, safety margins or detailed grading of a management measure – is too detailed for inclusion in the ISA Summary, but is available in the license application or in the ISA and ISA supporting documentation. Values in Table B-2 for Controlled Parameter Limits have built-in safety margins, the values for which and supporting computations are available in the facility's ISA.

Tables B-1 and B-2 include a column entitled "*Management Measure Grading*" that provides a general indication of what level of grading the applicant proposes to apply to management measures. Detailed information on each grading method (e.g. what constitutes a "high" grading of training versus an "intermediate" level of preventive maintenance) will be presented in the ISA.

TABLE BC-1

LIST OF ACCIDENT SEQUENCES FOR URANIUM DISSOLVER AND COMPARISON OF MATRIX RISK FACTORS TO THE PERFORMANCE REQUIREMENTS OF 10 CFR 70.61

General Accident Type and Number	Unmitigated Accident Consequences	Consequence Score (Table A-2)	Likelihood Score (Table A-1)	Matrix Risk Factor	Management Measure Grading	Comparison to 70.61 Performance Requirements
UD-1: Addition of too many uranium oxide solids	Exceed dissolver concentration limits, endanger criticality event	3 (High)	3 (Likely)	9	High	Exceed 70.61(b)
UD-2: Occupational exposure to acidic off-gases from the dissolver	Acid burns to skin and lungs, radiation exposure exceeding 10 CFR 20 limits from uranyl nitrate solution	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-3: Placement of uranium-bearing containers too close to dissolver	Violate spacing limits, endanger criticality event	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-4: Incorrect sequence of acid and solid addition	Splattering of solids and liquid, occupational radiation exposure	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-5: Plugging of in-line filters on dissolver discharge	Impeded drainage, spillage potential, occupational exposure potential	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-6: Loss of nitric acid supply containment, overflow from dissolver	Spillage of acid, occupational radiation risk potential	2 (Intermediate)	2 (Unlikely)	4	Intermediate	Exceed 70.61(c)
UD-7: Malfunction of hopper feed mechanism	Spillage of uranium oxide solids, radiation exposure potential, interaction with spilled acid	3 (High)	3 (Likely)	9	High	Exceed 70.61(b)
UD-8: Addition of excessive quantities of acid	Spillage of acid (and entrained solids), occupational radiation risk potential	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-9: Loss of containment for dissolver	Spillage and release of uranyl nitrate solution and solids	3 (High)	2 (Unlikely)	6	High	Exceed 70.61(b)

TABLE BC-2

LIST OF ACCIDENT SEQUENCES FOR URANIUM DISSOLVER, CONTROLLED PARAMETER, DESIGNATED IROFS (IDENTITY AND CATEGORY), AND MANAGEMENT MEASURES

General Accident Type and Number	Controlled Parameter	Controlled Parameter Limits	IROFS (Identity and Type[1])	Likelihood Score[2]		Management Measures
				Old	New	
UD-1: Addition of too many uranium oxide solids	Mass	15 kg max	PE: Weigh scale with interlock:2	3	-2	Procedures, operator training, weigh scale maintenance
	Geometry	8" diameter column	PE Fixed geometry: 3			
UD-2: Occupational exposure to acidic off-gases from the dissolver	Concentration of acid in air	<4 mg/l HNO_3	PE Ventilation system/scrubber: 2	3	0	Procedures, operator training, weigh scale maintenance
			A: Operator PPE: 1			
UD-3: Placement of uranium-bearing containers too close to dissolver	Spacing	>50 inches separation	A: Operational procedures (administrative control): 1 PE: floor design: 2	3	0	Training, procedures
UD-4: Incorrect sequence of acid and solid addition	Liquid Level ~~Procedure~~	Postings ~~N/A~~	PE Dissolver liquid level monitor: 2	3	0	Training, maintenance
			A: Operator ~~oversight~~: 1			
UD-5: Plugging of in-line filters on dissolver discharge	Discharge Flow Rate	5 gpm (minimum)	PE In-line flow monitor: 2	3	0	Maintenance, operator training
			A: Operator oversight: 1			
UD-6: Loss of nitric acid supply containment	Containment of HNO_3 supply tank	N/A	PE: acid-compatible construction materials, 2ndary containment pit: 2 AE: automatic closure valve on acid feed line to dissolver: 2	2	-2	Maintenance (valves, corrosion)
UD-7: Malfunction of hopper feed mechanism	Mass	<15 kg solids per dissolver loading	A: exposure control program and timely clean-up of spills: 1 P: containment for hopper: 2 AE: automatic level control for hopper contents: 2	3	-2	Maintenance (level controls, containment hardware), training
UD-8: Addition of excessive quantities of acid	Volume	<30 gallons	A: operator oversight: 1 PE: automatic shut-off valve: 2	3	0	Maintenance, procedures, training

TABLE BC-2 (Continued)

LIST OF ACCIDENT SEQUENCES FOR URANIUM DISSOLVER, CONTROLLED PARAMETER, DESIGNATED IROFS (IDENTITY AND CATEGORY), AND MANAGEMENT MEASURES

General Accident Type and Number	Controlled Parameter	Controlled Parameter Limits	IROFS (Identity and Type[1])	Likelihood Score[2]		Management Measures
UD-9: Loss of containment for dissolver	Vessel Integrity	N/A	A: operator oversight (including inspection for corrosion): 1 PE: secondary containment beneath dissolver: 3	2	-2	Maintenance, training

Note 1: Abbreviations for types of IROFS: AE = active engineered, PE = passive engineered, A = administrative, AUE = augmented administrative.
Note 2: '*Old Likelihood Score*' is reproduced in this column from Table C-1. '*New Likelihood Score*' is computed by subtracting from the Old Likelihood Score the total score assigned to all designated IROFS (listed in the IROFS column of this table). Scores for the effectiveness of an IROFS are listed in Table A-34.

BC.2 Section 2: Reporting of Process Risk Analysis in ISA Summary

Information developed in Section 1 for the risk assessment of the Uranium Oxide Dissolver process should be condensed for inclusion in the ISA Summary. One example of how this information could be summarized and presented follows.

PROCESS RISK ASSESSMENT

(a) Process Analyzed:

Process Identity:	Uranium Oxide Dissolver
Process Reference:	UD-05
Operational Description:	process for the batch dissolution of uranium oxide scrap in nitric acid
Safety Design Basis:	process safety is assured through adherence to the Double Contingency/Defense-in-Depth Principle

(b) Process Hazards:

Process Hazards Identified:

(i) **Nuclear criticality hazard**

(ii) **Chemical hazards**: nitric acid (≈70%): toxic by inhalation, ingestion, skin exposure; uranium oxide compounds (treated as a radiation hazard)

(iii) **Radiological hazards**: primarily associated with nuclear criticality; exposure from inhalation of uranium oxide dust and dissolver off-gases

(c) General Types of Accident Sequences:

General types of accident sequences for each identified hazard and possible initiating events follow:

Process Hazard Type	Initiating Events	General Accident Sequences
Nuclear Criticality	Exceed concentration limits Violate favorable geometry Violate spacing limits	Addition of too many solids Plugging of in-line filters Too close spacing of dissolver to containers containing dissolved uranyl nitrate Precipitation of uranyl nitrate due to lack of sufficient free acid
Chemical Hazards	Reagent or solids spills Inhalation of dissolver off-gases	Loss of containment (leaks, spills from tank and piping corrosion or failure) Overfilling of dissolver vessel Spillage of nitric acid Addition of too many solids Incorrect solids/acid mixing sequence Failure to use correct acid strength
Radiological Hazards	Spillage of uranium oxide solids during transfer to dissolver Loss of containment of dissolver contents	Nuclear criticality Occupational exposure from inhalation of dissolver off-gases or uranium dust

(d) Process Risk Assessment: Consult Table UD-1

(e) Items Relied on For Safety (IROFS): Consult Table UD-2

IROFS for each general type of accident sequence are identified in Table UD-2 by type and number. A list of each IROFS identified for this process and a brief description of the IROFS's function follow:

IROFS	IROFS Description
Weigh Scale with Interlock	Weigh scale to measure quantity of uranium oxide solids that are to be added to the dissolver for a batch dissolution. Interlock device prevents removal of weighing container from the scale if the solid quantity exceeds maximum permissible weight. Prevents nuclear criticality (Reference Accident Sequence UD0-1)
Fixed Geometry	Uranium dissolver is of a fixed cylindrical geometry to minimize occurrence of a nuclear criticality for complete filling with uranium scrap of the maximum permissible enrichment. Prevents nuclear criticality (Reference Accident Sequence UD-1)
Ventilation System	Exhaust fan and ventilation system (including a scrubber system) to capture any acidic off-gases from the dissolver that may contain uranyl nitrate and pose health and radiation risks to the worker. Protects against exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequence UD-2)
Personal Protective Equipment (PPE)	PPE worn by the dissolver operator is designed to protect against splashes of uanyl nitrate-bearing acid solutions. Protects against exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequence UD-2)
Vessel Spacing Procedures	Procedures to prevent the placement of any container brought into the dissolver room (or containing uranyl nitrate solution produced in a batch dissolution) from being placed too close to the dissolver so as to prevent a nuclear criticality. (Reference Accident Sequence UD-3).
Liquid Level Monitors	Automatic level monitors for use in the uranium dissolver and nitric acid bulk storage tank. These active engineered controls protect against overfilling of the dissolver or acid tank through sounding of alarms to prompt operator action. Protects against spillage of uranyl nitrate-bearing solution and/or nitric acid and concomitant worker exposures. (Reference Accident Sequence UD-4).
Operator Oversight	Operator procedures to ensure correct measurement of the quantities of solids and acid added to the dissolver, sampling and analysis of the dissolver discharge, prompt clean-up of spills, monitoring of filter media for plugging, etc. Protects against exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequences UD-4, UD-5, UD-8, UD-9)
In-Line Flow Monitors	Flow monitors are installed on the dissolver discharge line to detect any blockage or reduced flow across filter media that could, if not corrected, result in back-up and spillage of the uranyl nitrate solution. Protects against exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequence UD-5)

Materials of Construction	Dissolver vessel, piping, acid bulk storage tanks and associated measurement devices are manufactured of materials that provide suitable chemical resistance to corrosive dissolver conditions so as to prevent loss of solution containment. Protects against exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequence UD-6)
Automatic Closure Valves	Automatic closure valves on the acid feed line are designed to allow only a measured quantity of acid to be placed into the dissolver. Protects against spillage of acid, violent chemical reaction and exceeding acute chemical exposure standards and Part 20 radiation exposures. Fail-safe design (Reference Accident Sequence UD-6)
Automatic Level Control	Automatic level control on the uranium oxide feed hopper serves to prevent the overfilling of the hopper and loss of containment. Protects against spillage of oxide solids, nuclear criticality and Part 20 radiation exposures. Self-indicating design (Reference Accident Sequence UD-7)
Secondary Containment	Secondary containment on the floor beneath the dissolver is designed to collect any solids, acid or uranyl nitrate that is spilled during the batch loading or emptying of the dissolver. Designed to as to protect against nuclear criticality, exceeding acute chemical exposure standards and Part 20 radiation exposures (Reference Accident Sequence UD-9)

(f) Sole Items Relied on For Safety (IROFS):

There are no sole items relied on for safety for the Uranium Dissolver.

TABLE UD-1

LIST OF ACCIDENT SEQUENCES FOR URANIUM DISSOLVER AND COMPARISON OF MATRIX RISK FACTORS TO THE PERFORMANCE REQUIREMENTS OF 70.61

General Accident Type and Number	Unmitigated Accident Consequences	Consequence Score (Table A-2)	Likelihood Score (Table A-1)	Matrix Risk Factor	Management Measure Grading	Comparison to 70.61 Performance Requirements
UD-1: Addition of too many uranium oxide solids	Exceed dissolver concentration limits, endanger criticality event	3 (High)	3 (Likely)	9	High	Exceed 70.61(b)
UD-2: Occupational exposure to acidic off-gases from the dissolver	Acid burns to skin and lungs, radiation exposure exceeding 10 CFR 20 limits from uranyl nitrate solution	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-3: Placement of uranium-bearing containers too close to dissolver	Violate spacing limits, endanger criticality event	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-4: Incorrect sequence of acid and solid addition	Splattering of solids and liquid, occupational radiation exposure	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-5: Plugging of in-line filters on dissolver discharge	Impeded drainage, spillage potential, occupational exposure potential	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-6: Loss of nitric acid supply containment, overflow from dissolver	Spillage of acid, occupational radiation risk potential	2 (Intermediate)	2 (Unlikely)	4	Intermediate	Exceed 70.61(c)
UD-7: Malfunction of hopper feed mechanism	Spillage of UO_2 solids, radiation exposure potential, interaction with spilled acid	3 (High)	3 (Likely)	9	High	Exceed 70.61(b)
UD-8: Addition of excessive quantities of acid	Spillage of acid (and entrained solids), occupational radiation risk potential	2 (Intermediate)	3 (Likely)	6	Intermediate	Exceed 70.61(c)
UD-9: Loss of containment for dissolver	Spillage and release of uranyl nitrate solution and solids	3 (High)	2 (Unlikely)	6	High	Exceed 70.61(b)

TABLE UD-2

LIST OF ACCIDENT SEQUENCES FOR URANIUM DISSOLVER, CONTROLLED PARAMETER, DESIGNATED IROFS (IDENTITY AND CATEGORY), AND MANAGEMENT MEASURES

General Accident Type and Number	Controlled Parameter(s)	Controlled Parameter Limits	IROFS (Identity ,Type and Effectiveness Score[1])	Likelihood Score[2]		Management Measures
				Old	New	
UD-1: Addition of too many uranium oxide solids	Mass	15 kg max	PE: Weigh scale with interlock: 2	3	-2	Procedures, operator training, weigh scale maintenance
	Geometry	8" diameter column	PE Fixed geometry: 3			
UD-2: Occupational exposure to acidic off-gases from the dissolver	Concentration of acid in air	<4 mg/l HNO_3	PE Ventilation system/scrubber: 2	3	0	Procedures, operator training, weigh scale maintenance
			A: Operator PPE: 1			
UD-3: Placement of uranium-bearing containers too close to dissolver	Spacing	>50 inches separation	A: Operational procedures (administrative control): 1 PE: floor design: 2	3	0	Training, procedures
UD-4: Incorrect sequence of acid and solid addition	Liquid Level ~~Procedure~~	Postings ~~N/A~~	PE Dissolver liquid level monitor: 2	3	0	Training, maintenance
			A: Operator ~~oversight~~: 1			
UD-5: Plugging of in-line filters on dissolver discharge	Discharge Flow Rate	5 gpm (minimum)	PE In-line flow monitor: 2	3	0	Maintenance, operator training
			A: Operator oversight: 1			
UD-6: Loss of nitric acid supply containment	Containment of HNO_3 supply tank	N/A	PE: acid-compatible construction materials, 2^{ndary} containment pit: 2 AE: automatic closure valve on acid feed line to dissolver: 2	2	-2	Maintenance (valves, corrosion)
UD-7: Malfunction of hopper feed mechanism	Mass	<15 kg solids per dissolver loading	A: exposure control program and timely clean-up of spills: 1 P: containment for hopper: 2 AE: automatic level control for hopper contents: 2	3	-2	Maintenance (level controls, containment hardware), training
UD-8: Addition of excessive quantities of acid	Volume	<30 gallons	A: operator oversight: 1 PE: automatic shut-off valve: 2	3	0	Maintenance, procedures, training
UD-9: Loss of containment for dissolver	Vessel Integrity	N/A	A: operator oversight (including inspection for corrosion): 1 PE: secondary containment beneath dissolver: 3	2	-2	Maintenance, training

Note 1: Abbreviations for types of IROFS: AE = active engineered, PE = passive engineered, A = administrative, AUE = augmented administrative.
Note 2: '*Old Likelihood Score*' is reproduced in this column from Table UD-1. '*New Likelihood Score*' is computed by subtracting from the Old Likelihood Score the total score assigned to all designated IROFS (listed in the IROFS column of this table). Scores for the effectiveness of an IROFS are listed in Table A-34.